4. DEEP TUNNEL PUMP STATION

The Deep Tunnel Pump Station will be a below-grade facility with an above-ground building. The facility will be designed to initially dewater up to the 97 percent capture volume, 310 million gallons (MG), within a 3-day period; with provisions to dewater 99 percent capture volume, 504 MG, in the future. Based on input from the City of Indianapolis Department of Public Works (DPW), the facility will be designed to dewater the Fall Creek/White River Tunnel at a rate between 64-170 million gallons per day (mgd). As a conservative measure for this preliminary design phase, the pump station has been preliminarily sized to accommodate a future firm capacity of 170 mgd to permit dewatering the tunnel 99 percent capture volume within a 3-day period. Variable frequency drives (VFD) for the pumps are proposed to provide flexibility with the dewatering rate. The tunnel dewatering rate will be determined during subsequent design phases of the project based on goals included in the City's Combined Sewer Overflow (CSO) Long Term Control Plan, as well as hydraulic/process considerations at the Southport Advanced Wastewater Treatment (AWT) Plant and the Belmont AWT Plant. The preliminary target sustained flow rate for the Deep Tunnel Pump Station is 150 mgd, as identified in The Interplant Connection Facilities Plan performed for the City in May 2004.

The Deep Tunnel Pump Station will be located in a shaft at the downstream end of the tunnel near CSO-117. The captured CSO will be conveyed to the proposed Interplant Connection Structure and diverted to either the Southport AWT Plant through the Interplant Connection Sewer, or via siphons under the White River to the Belmont AWT Plant. Dewatering the tunnel between storm events will increase the capacity of the tunnel to capture subsequent CSO events.

4.1 GENERAL FACILITY REQUIREMENTS

The facility is preliminarily designed to dewater up to 97 percent capture volume, and can be upgraded to dewater 99 percent capture with the addition of pumps in the future. All of the pumping slots, vertical piping, and suction piping should be installed during the initial construction phase to reduce construction complications when the

Deep Tunnel Pump Station is in operation should additional CSO capture volumes be required in the future.

Upon completion of the tunnel construction, the working shaft will be converted to a screening shaft. The captured CSO will pass through a coarse bar screen with 3-inch openings located in the working shaft adjacent to the shaft housing the Deep Tunnel Pump Station. A 90-inch diameter encased pipe will connect the two shafts. The electrical switchgear and instrumentation and control (I&C) equipment will be located in an isolated room within the Deep Tunnel Pump Station. The heating, ventilation and air conditioning (HVAC) equipment will be located in a facility at grade on the working shaft site. The above-grade portion of the facility is recommended to be a brick and block building approximately 100 feet by 200 feet in plan dimensions and 50 feet high. The architecture of the facility can be designed to blend in with the surroundings, or as desired by the DPW.

4.2 PRELIMINARY DESIGN AND OPERATING CONSIDERATIONS

The pump design should be based on normal operating conditions. The normal operating conditions at the suction side range from a full tunnel to a nearly empty tunnel. Extreme operating conditions represent rare events falling outside the normal operating range. The two scenarios defining the limits of the extreme operating conditions include:

- Maximum Head Scenario: Under this condition, the Deep Tunnel Pump Station will be pumping from the lowest water level (nearly empty tunnel) to the discharge elevation at the Interplant Connection Structure

- Minimum Head Scenario: Under this condition, the tunnel is surcharged due to extremely heavy rainfall and CSO collection. The excess overflows will be diverted using mechanical and automated controls or passively using weirs to prevent flooding the tunnel as discussed in Section 3 – Fall Creek/White River Tunnel

4. DEEP TUNNEL PUMP STATION

The preliminary Deep Tunnel Pump Station hydraulic design is based on the elevation information summarized in Table 4.1.

Table 4.1
Deep Tunnel Pump Station Hydraulic Summary

Tunnel Storage Volume range, MG	190 - 504
Tunnel Invert Elevation at Screening Shaft, ft.	±437 (above mean sea level) (±255 below grade)
Tunnel High Water Level (Tunnel Crown), ft.	±467 (above mean sea level) (±225 below grade)
Discharge Elevation into Interplant Connection Diversion Structure near CSO-117, ft.	±680[1] (above mean sea level)

[1] Based on Interplant Connection Facilities Plan, May 2004.

The depth of the Deep Tunnel Pump Station in relation to the CSO storage tunnel will be dictated by the net positive suction head available (NPSHA). The NPSHA is the absolute pressure at the eye of the pump impeller. For flooded suction, the NPSHA is calculated by subtracting the head loss in the pump suction piping and the absolute vapor pressure at the pumping temperature from the sum of the atmospheric pressure plus the static difference between the pump impeller and the tunnel invert. For suction lift, the NPSHA is calculated by subtracting the head loss in the pump suction piping, the absolute vapor pressure at the pumping temperature, and the static difference between the pump impeller and the tunnel invert from the atmospheric pressure. The NPSHA must be greater than the net positive suction head required (NPSHR) to prevent pump cavitation.

Flooded Suction:
$NPSHA = h_a - h_{vpa} + h_{st} - h_{fs}$

Suction Lift:
$NPSHA = h_a - h_{vpa} - h_{st} - h_{fs}$

Where:
h_a = absolute pressure on the water surface
h_{vpa} = head corresponding to vapor pressure of the liquid
h_{st} = static head
h_{fs} = suction piping losses

4. DEEP TUNNEL PUMP STATION

The piping losses in the suction and discharge piping have an impact on the pump rating and the required horsepower. In an effort to minimize dynamic losses and piping costs, the following velocity criteria should be used when selecting pipe sizes for the Deep Tunnel Pump Station:

- Pump suction piping: 2 to 5 feet per second
- Pump discharge piping: 3 to 8 feet per second

In addition, applicable codes and standards must be followed. At a minimum, the mechanical process systems design should be guided by Hydraulic Institute (HI) standards and American Society of Testing and Materials (ASTM) standards.

4.3 PUMP CONFIGURATION ALTERNATIVES

The Deep Tunnel Pump Station must be designed to convey CSOs containing solids and stringy materials with minimal clogging. For this reason, large pump passages, a minimum number of impeller vanes, and continuously increasing passage diameters are the preferred pump characteristics. These characteristics can be found in a non-clog centrifugal pump. Submersible pumps should not be considered feasible due to the large motors required and their associated maintenance. Vertical diffusion vane pumps have tight clearances and poor solids pumping capability. Split-case pumps have lower solids pumping capability compared to non-clog pumps. In addition, their horizontal footprint requirement is much greater than a centrifugal pump. Positive displacement pumps are not suitable for the elevated flows that will be conveyed.

Increasing the horizontal footprint will require a larger diameter shaft, thereby increasing the drilling cost. Therefore, a vertical arrangement is proposed for the pump station design. This will minimize the horizontal footprint required by the pumps.

4. DEEP TUNNEL PUMP STATION

Due to the static head that must be overcome, two alternatives were evaluated, single-stage and two-stage pumping. Single-stage pumping under high flow and high head conditions necessitates very large, high horsepower, non-clog centrifugal pumps capable of achieving the required lift. Two-stage pumping provides a wider flow range capability and uses smaller pumps. These smaller pumps would not be capable of achieving the lift in a single stage and should be operated in series. A number of manufacturers offer these types of pumps.

As previously discussed, the tunnel is planned to be dewatered within a 3-day period. The Deep Tunnel Pump Station should be sized for an ultimate firm capacity of 170 mgd, based on future 99 percent capture requirements (504 MG tunnel volume). A four pump configuration (three operating, one standby) is proposed to provide the ultimate firm capacity. Based on this configuration, each pump would be sized at a capacity of approximately 57 mgd. This design is flexible and adaptable to meet dewatering rates for both 95 percent capture (190 MG tunnel volume) and 97 percent capture (310 MG tunnel volume). In order to dewater 190 MG for 95 percent capture within a 3-day period, the pump station should be designed with a firm capacity of 64 mgd. Similarly, dewatering 310 MG for 97 percent capture in three days requires a firm capacity of 104 mgd. Both scenarios can be accomplished by installing three pumping units or trains, which will yield a firm capacity of 114 mgd (two operating, one standby) and cover both the 95 percent capture and 97 percent capture scenarios, with a fourth open pump slot if the Deep Tunnel Pump Station is expanded to dewater the 99 percent capture volume.

In summary, the pumps can be configured and installed in phases such that the firm capacity of the Deep Tunnel Pump Station will enable dewatering the tunnel within a 3-day period should additional CSO capture volumes be required in the future.

4. DEEP TUNNEL PUMP STATION

4.3.1 Alternative 1 – Single-Stage Pumps

From preliminary discussions with pump manufacturers, the flow and head required for the Deep Tunnel Pump Station can be accomplished with a four-pump arrangement (three operating, one standby). The pumps are capable of achieving the lift required in a single stage. Variable frequency drives are proposed to provide flow flexibility. Variable frequency drives modulate the pumps to provide a steady flow into the Southport or Belmont AWT Plants. Increased pump turndown capability is also required during tunnel surcharge conditions. The pump criteria are listed in Table 4.2.

Table 4.2
Preliminary Design Criteria Alternative 1 – Single-Stage Pumps

Ultimate firm pump station capacity, mgd	170
Pump criteria	
Number of pumps	4
Type of pump	Vertical Non-clog Centrifugal
Rated flow, gpm (mgd)	39,500 (57)
Rated head, ft.	275
Estimated operating head range, ft.	225-275
Estimated motor size, hp	3,500
Estimated total pump station installed, hp	14,000
Drive type	Variable Speed
Minimum pump station turndown, mgd	28
Pump suction header	
Diameter, in.	90
Discharge pipe and valves	
Main pump control valve	Metal Seated Ball Valve
Discharge Pipe and Control valve size, in	48

As shown in Figure 4.1, the suction header from the screening facility enters the lower level of the Deep Tunnel Pump Station. Individual isolation valves should be provided in the suction piping upstream of each pump. The pumps should be supported on the upper level above the main suction header. The motors may be mounted directly to the pump frame with a close-coupled arrangement or supported on a third level above the pumps with extended shafts connecting the pump and motor. Due to the large size, it is critical that the motor mounting arrangement be further investigated during the detailed design phase.

4.3.2 Alternative 2 – Two-Stage Pumps

At lower flow rates, it becomes increasing difficult to find a pump that will reach the desired head and flow in a single stage. Using a smaller, more standard pump, will increase the number of manufacturers and may reduce the equipment cost. The required flow and head can be achieved with an arrangement of four-pump trains (two pumps in each train). Of the pump trains, three should be operating while one is considered standby. However, smaller pumps create several related issues. The pumps must be arranged in series where the discharge from the first stage feeds directly to the suction of the second stage. This arrangement increases the number of valves and length of pipe, resulting in a comparatively larger Deep Tunnel Pump Station footprint. The electrical design would be based around standard electrical voltage equipment. However, due to the additional valves and related control equipment required with two-stage pumps, there may not be significant cost savings over the single-stage alternative. Variable frequency drives are not considered feasible for this configuration due to the complicated controls required for operating the pumps. The installations that have attempted VFDs with pumps in series have experienced shorter pump lives, increased bearing failures, broken shafts, and other failures. Therefore, VFDs on this two-stage pump configuration are not recommended. The Deep Tunnel Pump Station criteria for the two-stage alternative are shown in Table 4.3.

4. DEEP TUNNEL PUMP STATION

INSERT FIGURE 4.1

4. DEEP TUNNEL PUMP STATION

Table 4.3
Preliminary Design Criteria Alternative 2 – Two-Stage Pumps

Ultimate firm pump station capacity, mgd	170
Pump criteria	
Number of pump trains	4
Number of pumps in each train	2
Total number of pumps	8
Type of pump	Vertical Non-clog Centrifugal
Rated flow, gpm (mgd)	39,500 (57)
Rated head, ft.	150
Estimated operating head range, ft.	125-150
Estimated motor size, hp	2,000
Estimated total pump station installed, hp	16,000
Drive type	Constant Speed
Minimum pump station turndown, mgd	57
Pump suction header	
Diameter, in.	90
Discharge pipe and valves	
Main pump control valve	Metal Seated Ball Valve
Discharge Pipe and Control valve size, in	48

As shown in Figure 4.2, the suction header from the screening facility would enter the lower level of the Deep Tunnel Pump Station. Isolation valves should be provided in the suction piping upstream of each pump. The pumps should be supported on the upper level above the main suction header.

4. DEEP TUNNEL PUMP STATION

Figure 4.2

4.3.3 Alternatives Comparison

The advantages and disadvantages of each alternative are outlined in Table 4.4. The general recommendation at this preliminary stage of design is to use the single-stage pump configuration, because the least number of pumps used as possible will minimize the Deep Tunnel Pump Station cost and reliability concerns.

Table 4.4
Deep Tunnel Pump Station Alternatives Comparison

Alternative 1 – Single-Stage Pumps	
Advantages	♦ Eliminates control issues and complications associated with two-stage lift ♦ Allows for use of variable speed drives ♦ Reduced number of valves and pipes ♦ Reduced pump station footprint ♦ Increased reliability due to fewer components that can fail
Disadvantages	♦ Requires special pump design and limits number of potential suppliers ♦ Increased crane capacity requirements
Alternative 2 – Two-Stage Pumps	
Advantages	♦ Standard sized pumps and valves ♦ Reduced crane capacity requirements
Disadvantages	♦ Less reliability due to increased number of components that can fail ♦ Higher cost due to increased number of pumps, motors, valves and piping ♦ More complicated control sequencing

4.4 ADDITIONAL PUMP STATION EQUIPMENT

The cleaning of the screening facility is critical to the operation of the system as partially to fully clogged screens will reduce the capacity of the pump station which could result in the surcharge and reduced storage capacity of the screening shaft and main tunnel. In the screening facility, as shown in Figures 4.1 and 4.2, a coarse bar screen (fixed) with 3-inch openings and a screening shaft crane with rake and clamshell bucket will be utilized for debris removal. A coarse bar screen with 3-inch openings has been considered for this application, but should be further evaluated in future phases of the project. The future designer may refer to the Corps of Engineers manual for storm water pump stations, EM 1110-2-3102, paragraph 6-4(b), as a guideline. The rake and clamshell will descend down the screen shaft to the bottom of the screen while collecting accumulated debris. A hoist will elevate the clamshell back to the surface where the debris can be dropped into a hopper, dumpster or other dumpsite. Typically these systems are designed to run automatically or an operator can operate the unit with a wireless remote or plug-in pendant. During future design phases, alternative cleaning systems may also be evaluated prior to equipment selection.

Either alternative will require additional equipment to make the Deep Tunnel Pump Station functional. The additional equipment required includes a compressed air system and piping for valve actuation. Pneumatic valves are recommended because the controls and solenoid valves can be mounted remotely from the valve and the valve can still be actuated even if it becomes submerged. This is especially important if a seal fails and the Deep Tunnel Pump Station begins to flood, as electric actuators may become damaged if submerged. A surge tank or other appropriate surge suppression equipment will be required to control the discharge piping pressure upon pump power failure. The surge equipment type and size should be determined based on the results of a detailed transient analysis of the Deep Tunnel Pump Station during the design phase. As stated previously, the bar screen facility and associated cleaning mechanism will be required to remove large particulates from the flow stream. These items are shown in Figures 4.1 and 4.2.

4. DEEP TUNNEL PUMP STATION

With either arrangement, the discharge piping from each pump will be routed up the shaft. Individual discharge lines will be provided to:

- Maintain a high scouring velocity to prevent solids from settling out in the vertical run of piping
- Physically isolate the pumps from each other; the pumps will be easier to maintain and actuate
- Allow for each header to be vented to the surge tank for passive surge protection

Sump pumps will also be required to dewater any seepage or leakage that may occur in the Deep Tunnel Pump Station. The sump pumps also offer a means for draining the main suction header for inspection or maintenance purposes, if required. The size of the sump pumps should be evaluated during detailed design when more information is available on the soil composition and anticipated seepage rates.